DTU Library

Instrumentation for an X-ray spectrometer

Skaarup, P.

Publication date:
1979

Document Version
Publisher's PDF, also known as Version of record

Citation (APA):
Skaarup, P. (1979). *Instrumentation for an X-ray spectrometer*. Risø National Laboratory. Risø-M No. 2184

Risø-M-2184

A Computer Controlled CAMAC Based Instrumentation For an X-Ray Spectrometer

Per Skaarup

Abstract. A description is given of an instrumentation for control of an X-ray spectrometer used in solid state physics experiments. The instrumentation includes an on-line PDP-11/34 and a CAMAC system. Details are given of the operating software.

INIS Descriptors
CAMAC SYSTEM
ON-LINE CONTROL SYSTEMS
PDP COMPUTERS
SOLID STATE PHYSICS
X-RAY SPECTROMETERS

Risø National Laboratory, DK 4000 Roskilde, Denmark
July 1979

ISBN 87-550-0610-8
ISSN 0418-6435

TABLE OF CONTENTS

1. INTRODUCTION

An important technique in solid state physics is X-ray scattering. Within the last years this technique has become more important because of the introduction of rotating anode X-ray generators which greatly increase the intensity of the X-ray beam. and the construction of dedicated storage rings in connection with synchrotrons which give an even greater intensity. To utilize these new possibilities, we have built a universal computer controlled X-ray spectrometer. The spectrometer is transportable and is used either at a new X-ray generator at Risø or at a synchrotron in Hamburg. This report describes the instrumentation built for the spectrometer.

The X-ray generator and the main part of the spectrometer including the electronic instrumentation was granted by the Danish Natural Science Research Council. A smaller part was financed by Risø. Design and construction took place at Risø and at the H.C. Ørsted Institute, University of Copenhagen.

2. GENERAL DESCRIPTION

The mechanical part of the spectrometer is shown in fig. 1. In an experiment, crystals are mounted on the monochromator table, the sample table, and the analyser table. X-rays scattered by the crystals are counted in a detector on the detector arm. The crystals are mounted on goniometers so that their orientation can be adjusted. The movement of the goniometers as well as of the spectrometer axis are controlled by stepping motors. The gearing is such that a precision of 0.001° is achieved. Compared with a neutron spectrometer the X-ray spectrometer is of much smaller dimensions, in particular due to the absence of the heavy shielding.

The high rate of data acquisition and the complexity of the control of the many axes call for a computer system with some sort of mass storage capabilities. The computer chosen for this instrumentation is a 28k words PDP-11/34 with a dual floppy disk unit as back-up media. The control of the axes is accomplished through CAMAC motor control modules connected to stepping motor drives. The CAMAC crate also contains scalers, timer, modules for drive of a numeric display, and a module for readout of a digital voltmeter. The nuclear channels with amplifiers, single channel analysers, and supply for two X-ray detectors are contained in a NIM-bin. A block diagram of the instrumentation is shown in figs. 2 and 3. A photo of the instrumentation is shown in fig. 4.

The computer runs under the real time software system RT-11 with the user software written in BASIC. A few routines are coded in assembly language. Among these are the driver for the CAMAC controller and display routines.

The computer has the supervisory control of the system. The experimenter communicates with the computer through a DECwriter terminal. He can do all programming in BASIC language including CAMAC operations.

A typical measuring procedure for the spectrometer has the following sequence of operations: calculation of the angles, adjusting of the spectrometer axis, resetting of scalers and start of counting, reading-out of measured data and axis positions, and storing on floppy disk of the data read.

Data reduction and evaluation of measured data are most often performed on the system itself with BASIC-programs written for that purpose. But since the floppy disks conform to IBM 3740 standard, measured data saved on floppies may be transferred to any computer system capable of reading IBM 3740, i.e., Risø's B6700 central computer.

3. DETAILED DESCRIPTION OF THE INSTRUMENTATION

3.1. Motor Control System

All motors are bifilar SLO-SYN stepping motors. Two types are used: M061-FD08 with a maximum speed of 2000 steps/sec, and M092-FD09 with a maximum speed of 1200 steps/sec. The motors are controlled from CAMAC modules P1062, connected to motor drives P1073. [x)]

Stepping Motor Control P1062

This CAMAC module can control a stepping motor either by order from the dataway, or by manual operation of switches on the front panel. In addition, it holds information on the position of the motor.

One 20 bit register in the module keeps track of the motor position as it acts as an up/down counter of the steps supplied from the module to the motor drive. This register can be set or read from the dataway.

Another 20 bit register controls the stepping of the motor. This register is loaded from the dataway with direction and number of steps necessary to move the motor to the wanted position. The register is then counted down to zero while pulses are generated to the motor drive. The frequency of the pulses decides the step rate of the motor. Three step rates 1, 2, or 3 may be chosen with a switch on the front of the module. Each of the three rates may be adjusted with potentiometers in the module.

Typical settings for motor M092 would be: step rate 1 = 5 Hz, step rate 2 = 100 Hz, step rate 3 = 1100 Hz.

---

x) P-numbers refer to Risø constructions.

At step rate 3 acceleration and deceleration circuits ensure that no steps are lost during start or stop of the motor. The acceleration and deceleration periods are adjustable, and so is the starting speed. For the type of motors used here, the start speed should be in the range of 400-500 steps/sec in order to avoid the regions below the speed where self-resonance in the motor may cause loss of steps.

The motors may be run under manual control with push-buttons on the front panel for positive and negative directions. Use of these push-buttons together with the step rate selection switch allows the user to drive a motor with high speed close to a wanted position and then with slow speed to the exact position.

The module accepts limit switch input signals either at the front panel connector or at the dataway patch bus P1. Such a signal will disable the output from the module for one direction of rotation or for both directions depending on a strapping in the module.

The module generates control signals to the power supply in the motor drive and to the air bearings on the axes. These control signals are generated when the 20 bit motor setting register is loaded from the dataway. The start of the setting is delayed 0.5 sec in order to ensure that the drive is on full power and the axes floating before the motor starts running. The two control signals are also generated when patch bus P2 is enabled with a switch on module P1073. This must be done prior to manual operation of a motor.

<u>Stepping Motor Drive P1073</u>

The drive is built around the SLO-SYN translator 1800CV. It accepts pulse input signals for positive or negative direction from the step motor control CAMAC module and generates the corresponding pattern to the stepping motor at the specified drive values, about 4A at 1.5V. In order to reduce the heat dissipation in the dropping resistors, the output voltage is reduced to half of the specified drive value when the motor is at standstill. This reduction is controlled with a signal from the CAMAC module.

The drives are built in the EURO-standard with six drives housed in a half-size 19" rack. The dropping resistors for all the drives are contained in a separate panel, P1080, at the uppermost position in the rack, which is equipped with forced cooling.

Limit Switch Input Module P1073

This simple CAMAC module acts as input for the limit switch signal which it transfers to patch bus P1. It also has a push--button for stop of the motors.

A switch, MAN/AUTO, on the module enables/disables patch bus P2. In the MAN position, the bus is enabled and the stepping motor modules set the signals which give full output voltage on the motor drives and activate the air to all the axes. All motors may then be manually run by means of the push-buttons on the step motor modules.

3.2. Display System

The display system consists of the following units:

- P1068 seven digit numeric displays.
- NE9044 binary to BCD converter CAMAC module with parallel output.
- NE9049B 24 bit parallel input CAMAC module.
- P803 LAM generator CAMAC module.

The display is driven from the NE9044 output module that transfers seven digits in BCD-code. The module is loaded from the dataway with either BCD-code or a 24 bit binary word which the module converts to BCD-output.

When the contents of a scaler is displayed, the output module is loaded with the binary value and performs the conversion to BCD giving a display range of 0-9999999.

When a motor position is displayed, the 20 bit binary position information from the stepping motor control module is taken as a signed 19 bit word and by software converted to BCD-code before it is loaded to the output module giving a range of ÷524287 to +524287. This procedure is chosen since it is more convenient for the user to select a zero position for the spectrometer axes and then work with positive or negative positions of the axes.

Selection of the units to be displayed is done with a 12 position switch on the front panel of the display. The switch is read via the input module and decoded by software.

The display is updated 10 times a second. This rate is set by the LAM-generator module.

3.3. Counting system

The Hytec model 350 CAMAC module comprises four presetable 24 bit scalers. The scalers are here named after their subaddresses A(0)-A(3).

Two scalers, A(0) and A(1) are connected to the two nuclear channels and are thus used to count the detected photons. A third scaler, A(2), is connected to the NE9088 pulse generator and acts as timer. The count rate in the timer may be changed with switches on the pulse generator.

Scaler A(3) is used as preset scaler/timer. Preset stop is generated when A(3) is counted up to its maximum contents, 2^{24}. Then a level is set on the A(3) overflow output which is connected to the inhibit input on A(0)-A(3). The preset function is realized by loading A(3) with the difference between its maximum contents and the wanted preset value, and then counting A(3) in parallel with either A(0), A(1), or A(2), depending on which one should govern the preset stop.

Note that the contents of A(3) will often not be available for display because it is outside the range of the display, i.e., greater than 10^7.

3.4. Temperature Control System

Automatic setting of the temperature control is by means of a step-motor driven reference potentiometer in a proportional/integral regulation. The motor is run by a P1062 CAMAC module since this module can drive small stepping motors directly.

A Solartron digital voltmeter with scanner is used to read up to 10 temperature sensors and is interfaced through the P967 DVM control module.

4. SOFTWARE

The software works under the RT-11 operating system supplied by DEC. The software written particularly for this instrumentation may be divided in software delivered with the instrumentation and software written by the experimenter. The latter - the experimenter written software - is coded in RT-11/BASIC, but is not dealt with in this report. The software delivered with the instrumentation is partly in RT-11 assembler code and partly in RT-11/BASIC.

4.1. Assembler Programs

The main components of the assembler coded software are the CAMAC driver and the display routines.

The CAMAC driver makes it possible to communicate with CAMAC modules from both assembler and BASIC level. It also includes binary to BCD converter and vice versa. From BASIC a CAMAC call has the form:

```
CALL CFSA (F%,N%*512%+A%*32%,D,Q%)
```

where the parameters have the following meaning:

F% Function code

N% Station number of addressed module

A% Subaddress in module

D Data to or from module

Q% Status

The notation % after a symbol means that the symbol is a 16 bit integer word. Severai examples on the use of this call can be seen in the listing of BASIC programs in the appendix.

The display routines do the following tasks: On each interrupt from the LAM-generator, the selector switch on the display is read ar . the value decoded in a table in order to find the module number and subaddress of the register to be displayed. The contents of the register is then read and the data transferred to the display output module, either directly or via a binary to BCD conversion routine.

The display is only active after the display routine has been enabled with the BASIC call

CALL EDPL

The call starts the LAM-generator and enables interrupt in the CAMAC controller.

Before the monitor is called from BASIC with the command BYE, the display must be disabled with the call

CALL DDPL

The call stops the LAM-generator. If the display is not disabled the LAM-generator will continue to send interrupt requests to a now no longer existing interrupt service routine, with the consequence that the monitor will be lost and the system much be bootstrapped again.

Other assembler coded routines are used to set or read the position control register in the stepping motor control modules. The BASIC call that sets a new value is

CALL SETM (I%, M(I))

while the call that reads a register is

CALL GETM (I%, M(I))

In both calls, I% is the motor number where $1\% \leq I\% \leq 6\%$ and M(I) is the position of the motor where $\div 524287 < M(I) < +524287$.

All the above-mentioned calls may be given either as immediate BASIC calls or included in statement lines in BASIC programs.

Listing of the assembler coded programs is not included in this report but is available on request.

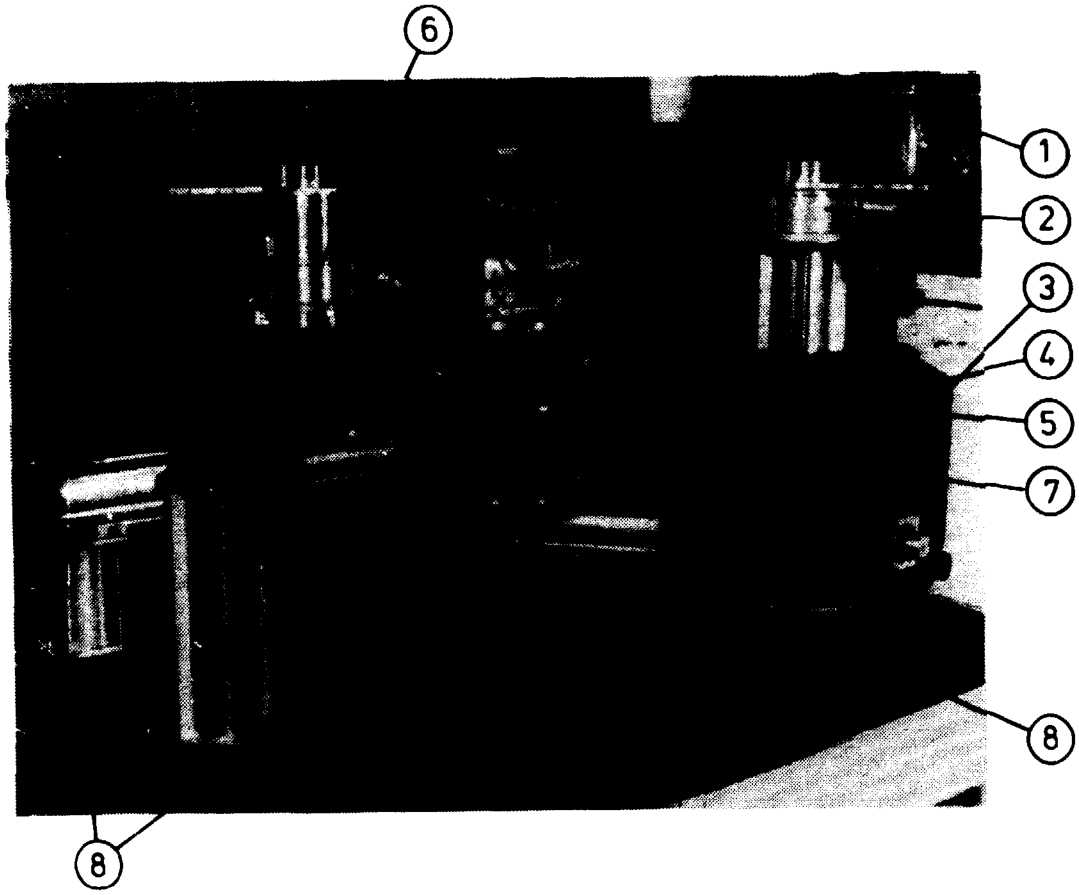
4.2. BASIC-programs

The BASIC programs delivered with the instrumentation are eight subroutines that can control axis positioning, start/stop of measurement, and read out of data from CAMAC modules. The user should append the eight routines to his BASIC program, but for documentational reasons it is not recommended to make changes in them even though it is quite easy.

The routines are summarised below; a detailed explanation and a full listing are given in the appendix.

BASIC subroutines:

GOSUB 24000	Clear flags in motor modules.
GOSUB 25000	Read digital voltmeter.
GOSUB 26000	Initialize motor positions.
GOSUB 27000	Measurement finished?
GOSUB 28000	Clear scalers, preset, start.
GOSUB 29000	Read scalers and motors.
GOSUB 3000n	Setting of motor n.
GOSUB 3100n	Test if motor n is running.



1. Beam tube from X-ray generator.
2. Monochromator table.
3. Monochromator arm.
4. Sample arm.
5. Sample table.
6. Analyser table.
7. Detector arm.
8. Air bearings.

Fig. 1. X-ray spectrometer.

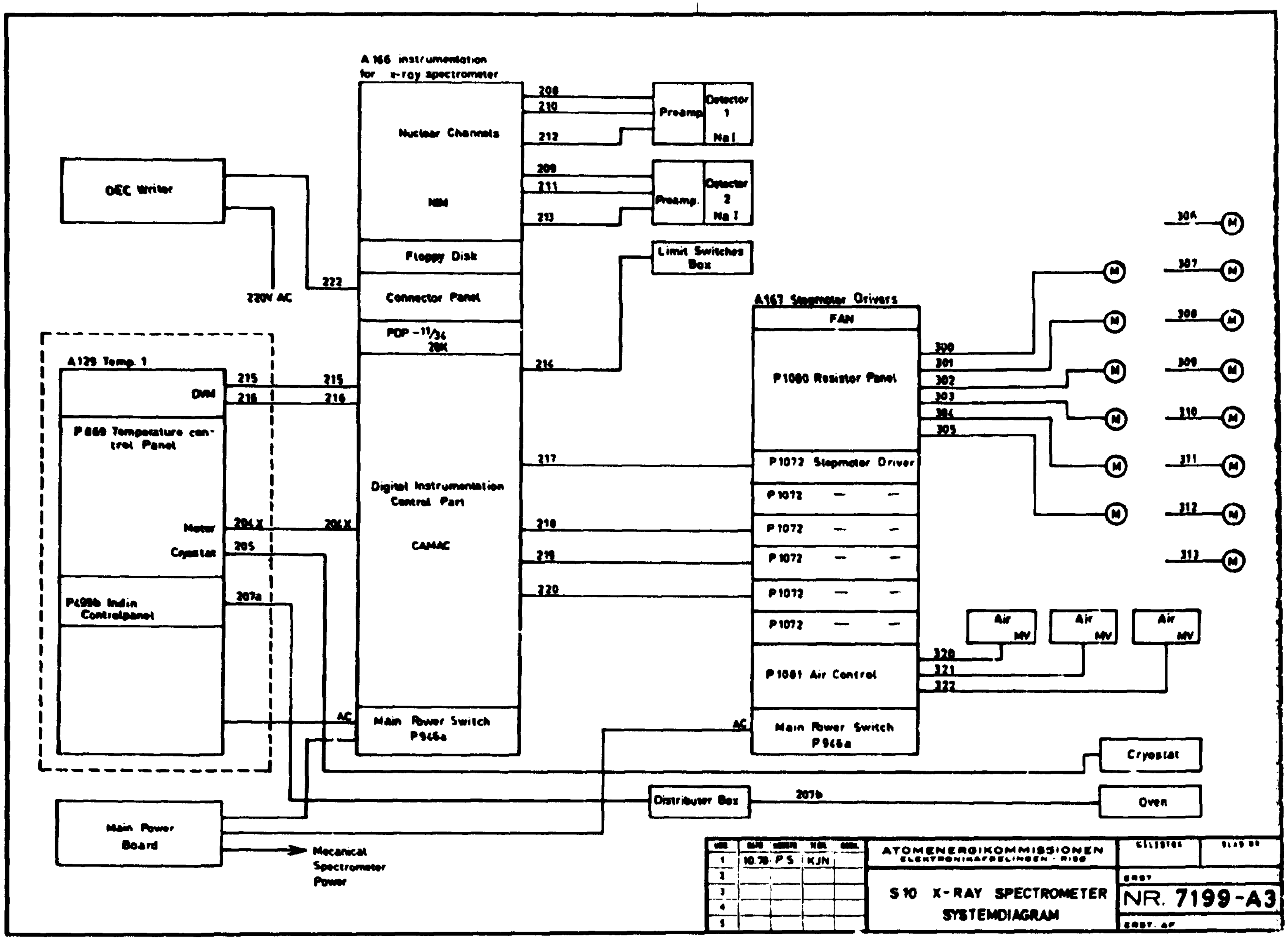


Fig. 2. X-ray spectrometer. Block diagram of the instrumentation.

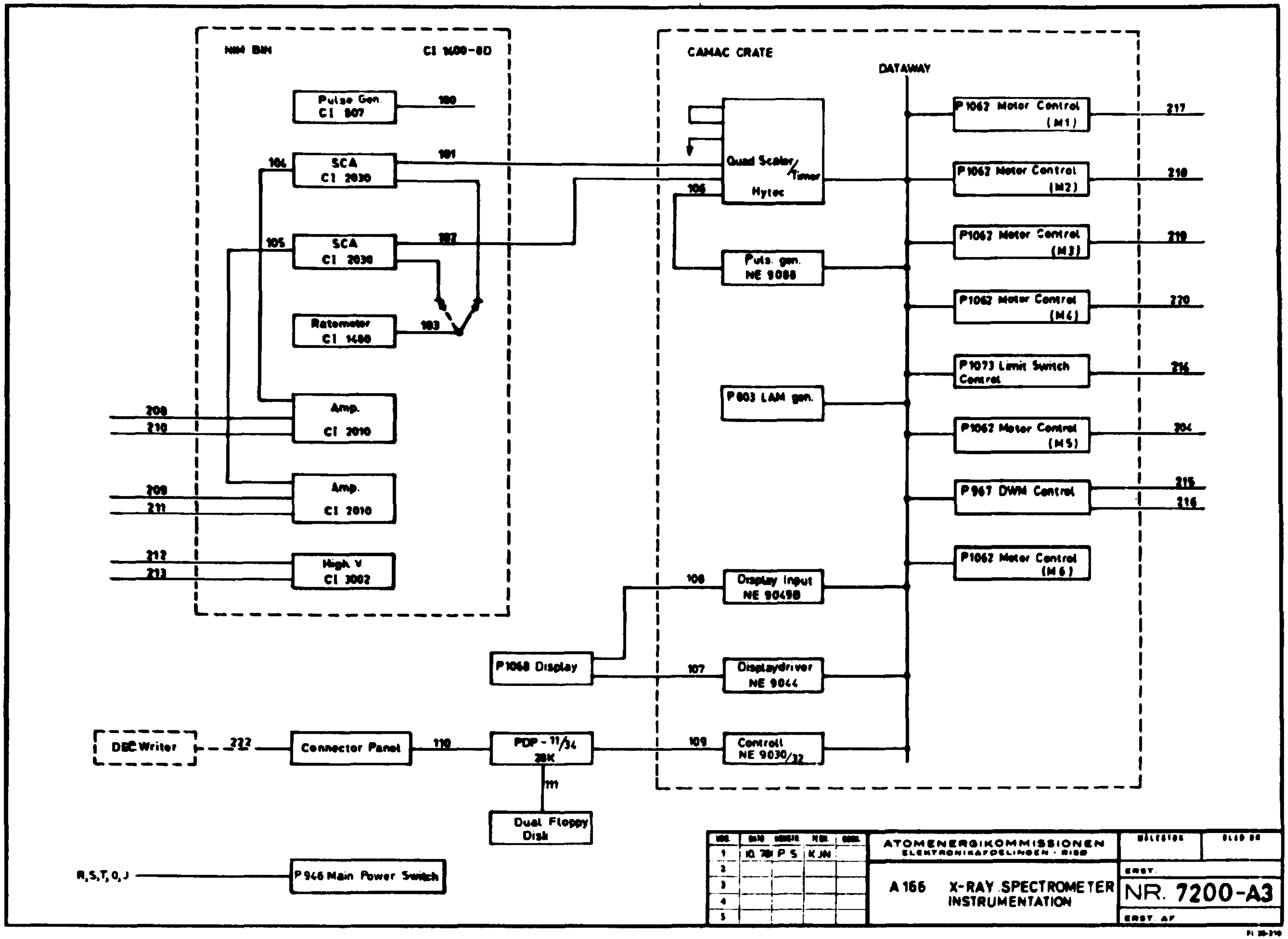


Fig. 3. X-ray spectrometer. Block diagram of the instrumentation.

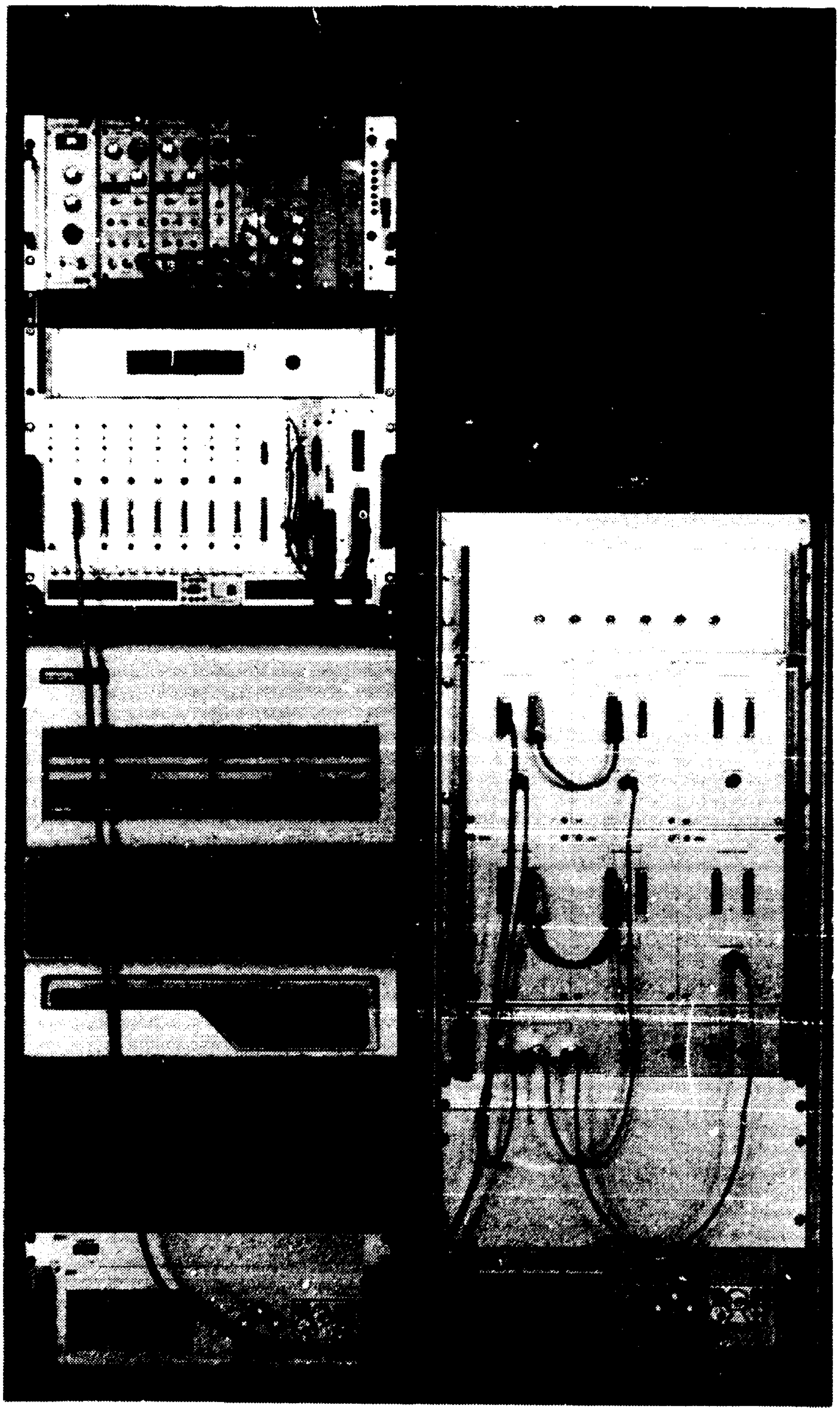


Fig. 4. Photo of X-ray spectrometer instrumentation.

APPENDIX

X-RAY SPECTROMETER BASIC SUBROUTINES

GOSUB 24000 Clear Q-Flags

Sets flags Q0% to Q6% equal to 0%.

GOSUB 25000 Read Digital Voltmeter

Calls with C% = channel number, where 0%≤C%≤9%. The routine returns with V = read value in millivolt.

GOSUB 26000 Initialize Motor Positions

Prints the six present positions on the terminal and asks CHANGE (1,0)?. Respond with 0 if no change is wanted and the routine then returns. Respond with 1 if a change in any of the positions is wanted. The routine asks for input of the new positions; input the new values separated by commas.
÷524287<position<524287.

GOSUB 27000 Measurement Finished

The routine may be called after the scalers have been preset and started to see if the preset value has been reached. The routine returns P% = 0% if the scalers are still counting, and P% = 1% if they have been stopped.

GOSUB 28000 Clear, Preset, and Start Scalers

The routine is called with T = preset value; $0<T<10^7$. The routine clears the scalers, presets the preset scaler, and starts counting.

GOSUB 29000 Read Scaler and Motor Positions

The routine reads the contents of the scalers and the positions of the motors. It returns the scaler contents in S0, S1, S2, and S3, the motor positions in M(1) to M(6).

Motor Setting Routine

The routine is called with one of the following calls:

```
GOSUB 30001 set motor 1   to position A1 or A1-50
GOSUB 30002 set motor 2   to position A2 or A2-50
GOSUB 30003 set motor 3   to position A3 or A3-50
GOSUB 30004 set motor 4   to position A4 or A4-50
GOSUB 30005 set motor 5   to position A5 or A5-50
GOSUB 30006 set motor 6   to position A6 or A6-50
GOSUB 30000 set motor M0% to position P1 or P1-50
                         -524287<position<524287
                                1%<=M0%<=6%
```

The routine calculates the number of steps necessary to drive the motor into position and loads the number into the motor module which then starts to step the motor. When the module has delivered all the steps, the motor stops, but the motor setting routine does not wait for that, it just starts the setting.

If the setting is in the positive direction, the motor will be run to the specified position A1, A2, etc.

If the setting is in the negative direction, the motor will be run to a position 50 steps lower than the specified one, in order to compensate for backlash in the goniometer. To get the specified position, the routine must be called once more.

For each motor started, the routine returns with the corresponding flag B1-B6 set negative for negative rotation and positive for positive rotation.

Routine to Test if a Motor Is Running

The routine is called with one of the following calls:

GOSUB 31001 test if motor 1 is still running
GOSUB 31002 test if motor 2 is still running
GOSUB 31003 test if motor 3 is still running
GOSUB 31004 test if motor 4 is still running
GOSUB 31005 test if motor 5 is still running
GOSUB 31006 test if motor 6 is still running

The routine reads the status of the motor control modules and returns the status as Q1%-Q6% for motors 1-6. The status, Q1%-Q6%, may be either 0% or 1%. If it is 1% it means that the corresponding motor has been started by the motor setting routine and is now stopped. If the status is 0% the motor is still running or has never been started.

If a motor stops by a limit switch action, the routine prints a message on the terminal and the program returns to command mode.

The routine checks the direction of rotation of the motors. If a motor stops after a negative rotation, the position will be some steps too low because of the backlash compensation. The motor setting routine is then automatically recalled in order to run the motor into position with positive rotation. The status is set to 1% only after this last run.

Listing of BASIC Subroutines

```
24000 REM CLEAR Q-FLAGS IN MOTOR MODULES ********
24010 FOR I%=1% TO 6%
24030 CALL CFSA(10%,512%*(2%*I%+1%),P,Q%)
24040 NEXT I%
24050 Q1%=0% \ Q2%=0% \ Q3%=0% \ Q4%=0% \ Q5%=0% \ Q6%=0%
24060 RETURN
25000 REM READ DIG. VOLTMETER ********
25010 CALL 'DVM'(C%,V,R)
25020 V=V*10^(-2-R)
25025 RETURN
26000 REM INITIALIZE MOTOR POSITIONS ********
26005 DIM M(6)
26010 GOSUB 29000 \ REM READ PRESENT POSITIONS
26020 PRINT M(1),M(2),M(3),M(4),M(5),M(6)
26022 PRINT 'CHANGE (1,0) ';
26024 INPUT P% \ IF P%=0 THEN RETURN
26030 PRINT 'INPUT M1,M2,M3,M4,M5,M6=';
26055 INPUT M(1),M(2),M(3),M(4),M(5),M(6)
26060 FOR I=1 TO 6
26070 I%=I
26080 CALL SETM(I%,M(I)) \ REM SET NEW POSITIONS
26090 NEXT I
26140 GO TO 26010
27000 REM MEASUREMENT FINISHED?  **********
27010 CALL 'CFSA'(8%,512%*19%+32%*3%,P,P%)
27020 RETURN
28000 REM CLEAR SCALERS, PRESET, AND START MEASUREMENT ********
28005 FOR I%=0% TO 2%
28010 T9%=512%*19%+32%*I%
28020 CALL 'CFSA'(26%,T9%,P,P%)
28030 CALL 'CFSA'(9%,T9%,P,P%)
28050 NEXT I%
28060 T9=16-T+1.67772E+07 \ REM A(3)PRESET
28070 CALL 'CFSA'(16%,512%*19%+32%*3%,T9,P%)
28080 CALL 'CFSA'(26%,512%*19%+32%*3%,P,P%)
28090 RETURN
28100 REM
29000 REM READ SCALERS AND MOTOR POSITIONS ********
29010 CALL 'CFSA'(0%,512%*19%,S0,P%)
29020 CALL 'CFSA'(0%,512%*19%+32%,S1,P%)
29030 CALL 'CFSA'(0%,512%*19%+32%*2%,S2,P%)
29040 CALL 'CFSA'(0%,512%*19%+32%*3%,S3,P%)
29050 REM S0-S3: SCALER COUNTS
29060 FOR I=1 TO 6
29070 I%=I \ CALL GETM(I%,M(I)) \ REM READ POSITIONS
29080 NEXT I
29090 RETURN
29120 REM M(1)-M(6):MOTORPOSITIONS
29130 REM
```

```
30000 GO TO 30020 \ REM MOTOR SETTING *************
30001 M0%=1% \ P1=A1 \ GO TO 30030
30002 M0%=2% \ P1=A2 \ GO TO 30030
30003 M0%=3% \ P1=A3 \ GO TO 30030
30004 M0%=4% \ P1=A4 \ GO TO 30030
30005 M0%=5% \ P1=A5 \ GO TO 30030
30006 M0%=6% \ P1=A6 \ GO TO 30030
30010 REM  M0=MOTOR NUMBER  M9=STATION NUMBER
30020 REM  P1=NEW POSITION
30030 M9%=512%*(2%*M0%+1%)
30040 CALL GETM(M0%,P0) \ REM P0=PRESENT POSITION
30060 P2=P1-P0+.1*SGN(P1-P0)
30070 IF P2<-1 THEN 30160 \ REM NEG. DIR.
30080 IF P2>1 THEN 30120 \ REM POS. DIR.
30090 P2=0 \ GO TO 30190 \ REM NO SETTING
30120 P3=P2+524288 \ GO TO 30170 \ REM POS. DIR. BIT
30160 P3=-P2+50 \ REM BACKLASH COMPENSATION
30170 CALL 'CFSA'(17%,M9%,P3,Q0%) \ REM LOAD MOTOR DATA
30180 CALL 'CFSA'(10%,M9%,P2,Q0%) \ REM CLEAR Q
30190 IF M0%=1% THEN B1=P2 \ RETURN
30200 IF M0%=2% THEN B2=P2 \ RETURN
30210 IF M0%=3% THEN B3=P2 \ RETURN
30220 IF M0%=4% THEN B4=P2 \ RETURN
30230 IF M0%=5% THEN B5=P2 \ RETURN
30240 IF M0%=6% THEN B6=P2 \ RETURN
30250 STOP \ REM M0>6
30310 REM B1-B6 ARE DIRECTION FLAGS
30320 REM
31000 GO TO 31020 \ REM TEST IF MOTOR RUNNING *************
31001 M0%=1% \ P2=B1 \ P1=A1 \ GO TO 31040
31002 M0%=2% \ P2=B2 \ P1=A2 \ GO TO 31040
31003 M0%=3% \ P2=B3 \ P1=A3 \ GO TO 31040
31004 M0%=4% \ P2=B4 \ P1=A4 \ GO TO 31040
31005 M0%=5% \ P2=B5 \ P1=A5 \ GO TO 31040
31006 M0%=6% \ P2=B6 \ P1=A6 \ GO TO 31040
31010 REM  M0=MOTOR NUMBER  M9=STATION NUMBER
31020 REM  P1=NEW POSITION  P2=DIRECTION FLAG
31040 IF P2=0 THEN P%=1% \ GO TO 31170 \ REM NO SETTING
31045 M9%=512%*(2%*M0%+1%)
31050 CALL 'CFSA'(8%,M9%,P9,P%) \ REM TEST Q-FLAG(=P)
31060 CALL 'CSSA'(1%,M9%,Q0%,T9%) \ REM READ STATUS (=Q0)
31070 Q0%=Q0%-12%
31080 IF Q0%>3% THEN 31120
31090 IF Q0%<1% THEN 31120
31100 PRINT 'LIMIT SWITCH' \ STOP
31120 IF P%=0% THEN 31170
31130 IF P2<0 THEN  GOSUB 30030 \ P%=0
31170 IF M0%=1% THEN Q1%=P% \ RETURN
31180 IF M0%=2% THEN Q2%=P% \ RETURN
31190 IF M0%=3% THEN Q3%=P% \ RETURN
31200 IF M0%=4% THEN Q4%=P% \ RETURN
31210 IF M0%=5% THEN Q5%=P% \ RETURN
31215 IF M0%=6% THEN Q6%=P% \ RETURN
31230 STOP \ REM M0>6
31290 REM RETURN WITH FLAGS Q1,Q2,ETC.
```

Risø National Laboratory **Risø - M -** 2184

Risø - M - 2184

Title and author(s)	Date July 1979
A computer controlled CAMAC based instrumentation for an X-ray spectrometer Per Skaarup	Department or group Electronics Group's own registration number(s) R-6-79
pages + tables + illustrations	
Abstract	Copies to

A description is given of an instrumentation for control of an X-ray spectrometer used in solid state physics experiments. The instrumentation includes an on-line PDP-11/34 and a CAMAC system. Details are given of the operating software.

Available on request from Risø Library, Risø National Laboratory (Risø Bibliotek), Forsøgsanlæg Risø), DK-4000 Roskilde, Denmark
Telephone: (03) 37 12 12, ext. 2262. Telex: 43116